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Flanders Marine Institute

Scientific basis for a national approach to the phase-out of lead use in angling

Policy Information Brief
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Flanders Marine Institute (VLIZ)

Policy Information Brief

Introductory note

Flanders Marine Institute (VLIZ) can provide policy-relevant information free of charge at the request of its target groups, as well as on its own initiative. This information is made available in the form of policy information briefs (in Dutch: Beleidsinformerende nota's - BIN).

The content of the policy information notes is based on current scientific insights and objective information and data. VLIZ relies as much as possible on the expertise of coastal and marine scientists in the network of marine research groups in Flanders/ Belgium and the international network.

The policy information notes reflect the neutral and unbound character of VLIZ and strive for a maximum translation of the basic principles of sustainability and an ecosystem-based approach as endorsed in the European Integrated Maritime Policy and Coastal Zone Management.

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Content of the report

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1. The World Health Organisation (WHO) considers lead to be one of the ten chemicals of most concern in terms of public health.

2. The UNEP AEWA Plan of Action (UN Environment Programme - African-Eurasian Migratory Waterbird Agreement) Article 4.3.12 states that all Parties shall work together to provide further documentation on the nature and scale of the effects of lead fishing weights on waterbirds. The Parties will, as appropriate, seek alternatives to lead fishing weights, taking into account the impact of lead on waterbirds and water quality.

3. The Convention on the Conservation of Migratory Species of Wild Animals (CMS) states in Article 5.5.i that Parties shall prevent, reduce or control the release of harmful substances into the habitats of migratory species.

4. The Code of practice for the prevention and reduction of lead contamination in foods (CXP 56-2004) of the Food and Agriculture Organisation of the United Nations (FAO)/WHO, as drafted by the Codex Committee on Contaminants in Food (CCCF), states that lead-contaminated water is a major cause of lead contamination in food, with fishing lead and lead shot (in addition to major influx sources such as run-off/ drainage and atmospheric deposition) being responsible for local contamination.

5. The European Directive 2013/39/EU (i.e. Directive on Priority Substances) amending Directive 2000/60/EG (Water Framework Directive) and Directive 2008/105/EG as regards priority substances in the field of water policy, states that lead is part of the list of priority pollutants for which measures have to be taken at Community level in order to reduce discharges, emissions and losses into surface waters.

6. Pollution by hazardous substances, such as heavy metals, is included in the indicative list of pressures and impacts by Directive 2008/56/EG establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Framework Directive - MSFD).

7. Specifically for lead used and sold for gunshot and fishing tackle, a restriction proposal was developed by the European Chemicals Agency (ECHA) under the REACH Regulation (EC) No 1907/2006 (ECHA 2021).

8. In response to the AEWA provisions, at the EU level, Regulation (EU) 2021/57 amending Annex XVII to Regulation (EC) No 1907/2006 has already banned the firing or possession of gunshot with a lead concentration >1% w/w (mass fraction) in and around wetlands from 15 February 2023.

9. The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) included lead and lead compounds in the OSPAR list of chemicals for priority action in 1998.

10. In its 2015 position paper, the European Fishing Tackle Trade Association (EFTTA) called for a voluntary phase-out of the production, import, sale and use of lead weights heavier than 0.06 g by 2020 at the latest, and their replacement with suitable alternatives.

11. At the Benelux Inter-Parliamentary Council of 20 June 2014, a recommendation was adopted on restricting the use of environmentally harmful substances in fishing and promoting environmentally friendly alternatives.

12. The Programme of Measures for Belgian Marine Waters (2016-2021) to implement MSFD Art. 13 (Belgian State 2015) states that through Measure 29D it will promote alternatives to fishing lead, contributing to the achievement of the MSFD environmental targets concerning descriptor 8 'Pollutants'.

13. The Federal Commission for Energy, Environment and Climate of 16 March 2021 (CRABV 55 COM 408) states that the phase-out of fishing lead should be pursued and that it should be part of the second Programme of Measures for the Belgian Marine Waters (2022-2027).

14. The Federal Marine Litter Action Plan (Belgian State 2017) also states, by analogy with the Programme of Measures for the Belgian Marine Waters [12], that it will promote the introduction of alternatives to fishing lead.

15. The Flemish Water Code (Title 3 - Chapter 2 - Article 3.2.1) states that it is forbidden to throw or deposit objects or substances in the waters of the public hydrographic network or in the public sewers, to discharge contaminated or polluting liquids, or to introduce gases (provided that a permit is issued).

16. VLAREM II (Annex 2.3.1 'Basic environmental quality standards for surface water'; Article 3§4) categorises lead as a priority substance, and states that for all priority substances, measures must be taken aimed at its progressive reduction, in accordance with the Decree of 18 July 2003 on integrated water policy.

17. Resolution 408 (2014-2015) No. 3 on the reduction of the use of environmentally harmful substances in recreational fishing and the promotion of environmentally friendly alternatives' (adopted on 16 March 2016) aims to promote ecological alternatives in recreational fishing and to raise awareness among all stakeholders about the harmful effects of using lead sinkers.

18. Since 2019, an awareness-raising 'Code Lead Use' has been included on the Flemish fishing permit and in the Public Fishing Regulations, which states that lead is a toxic metal and calls for the use of lead-free alternatives.

19. In Flanders, the use of lead and zinc shot in hunting has been prohibited since 30 June 2008, as stipulated by the Decree of 28 October 1987 of the Flemish Executive on the use of firearms and ammunition in hunting in the Flemish Region. This ban was again confirmed by the Flemish Government Decree of 25 April 2014 laying down the conditions under which hunting can be carried out (Art. 10), which provides for the repeal/replacement of the Decree of 28 October 1987.

20. In addition to being a source of pollution for the environment, the use of lead entails direct health risks, especially during home-casting of lead. This releases slag and toxic fumes that can be inhaled and precipitate as very fine lead dust within a few dozen metres. Young children (and pregnant women) absorb four to five times more lead than adults when exposed, making them much more susceptible to the health risks of lead.

21. The (intentional) introduction of lead into surface waters contravenes the Belgian/Flemish legislation (cf. [15] and [16]).

22. Lead is used in angling because of its malleability, low melting point, high mass density, low cost and ease of processing. Within this framework, lead is used as a casting weight or weighting to the fishing line, and it is often incorporated into feeders and lures.

23. In 2019, Belgium had around 130,000 active anglers who together lost an estimated 10 to 17 tonnes of lead in public waters (both freshwater and saltwater) on an annual basis. The actual lead loss is probably even higher, as these figures do not include anglers who fish exclusively in private ponds.

24. The number of fishing permits for public inland waters increased by 30% in 2020 compared to 2019. This increase in new and inexperienced anglers implies a greater loss of fishing lead and an increasing environmental impact.

25. The financial impact of (more expensive) eco-friendly weights on the total annual hobby-related expenditure is rather limited. Furthermore, increased production of alternatives may in the future contribute to price reductions.

26. Almost every type of fish weight or lure can be replaced by an alternative (see also written question (no. 1002) of 11 September 2020 in the Flemish Parliament). Although the dynamics of alternative weights underwater (and in the air) may differ from those of their lead counterparts, they do not appear to have a significant impact on functional performance and are mainly a matter of habituation. Only for the very smallest lead weights (<0.06 g; cf. EFTTA 2015) the number of alternatives is limited and they have not yet been sufficiently tested by pole fishermen.

27. Care should be taken that the lead phase-out does not result in an increase in the use of other polluting or scarce materials, such as heavy metals or plastics (degradation to microplastics).

2. Background

2.1 Lead

Lead (Pb) is a naturally occurring heavy metal which, due to a number of practical properties (malleability, low melting point (327.5 °C), high mass density (11.34 g/cm³) and low cost), is used in a wide range of applications, including angling. However, the use of lead also involves a number of dangers. For example, lead particles may be ingested or inhaled during use (e.g. fishing) or treatment (e.g. melting). In addition, lead is a persistent, bioaccumulative toxic element (PBT). This means that lead particles and oxides permanently accumulate in any form of life and do not biodegradate. Consequently, lead losses in surface waters during fishing also contribute to the gradual accumulation of lead in the respective water bodies and the chemical pollution of the aquatic or marine environment (see also **2.3.2**).

2.2 Lead policy

2.2.1 International, European and regional framework

At the international level, the World Health Organisation (WHO) has been addressing the health risks associated with lead exposure for decades. Lead was also included in the list of the ten chemical substances of greatest concern for public health (www.who.int). The WHO and the Food and Agriculture Organisation of the United Nations (FAO) stated in the "Code of Practice for the prevention and reduction of lead contamination in foods" (CXP 56-2004) that water is a major source of lead contamination in food, with fish lead and lead shot (in addition to major influx sources such as run-off/drainage and atmospheric deposition) being responsible for local contamination. In addition, the Convention on the Conservation of Migratory Species of Wild Animals (CMS) states in Article 5.5.i that State Parties should prevent, reduce or control the release of harmful substances into the habitats of such species. Furthermore, at the Fifth Party Meeting (MOP5) of UNEP AEWA (African-Eurasian Migratory Waterbird Agreement) in 2012, Resolution 5.6 was adopted, with amendments for the AEWA Plan of Action, which states in Article 4.3.12 that all Parties shall work together to provide documentation on the nature and scale of the effects of lead fishing weights on waterbirds. The Parties will, as appropriate, seek alternatives to lead fishing weights, taking into account the adverse effects of lead on waterbirds and water quality.

In European water policy (Water Framework Directive, WFD - Directive 2000/60/EC), lead is part of the list of priority pollutants for which measures must be taken at Community level in order to reduce discharges, emissions and losses into surface waters (Directive Priority Substances - Directive 2008/105/EC, as amended by Directive 2013/39/EU). Pollution by hazardous substances, such as heavy metals, is also included by the Marine Strategy Framework Directive (MSFD - Directive 2008/56/EC) in the indicative list of pressures and impacts. Specifically for lead used and sold for gunshot and fishing tackle, the European Chemicals Agency (ECHA) is working on a restriction proposal (ECHA 2021) under the REACH Regulation (EC) No 1907/2006, with the aim of publishing a new European legal framework by spring 2023 (see **2.2.1.1**). In response to the AEWA provisions, at EU level, Regulation (EU) No 2021/57 amending Annex XVII to Regulation (EC) No 1907/2006 already banned the firing or possession of gunshot with lead concentrations >1% w/w in and around wetlands from 15 February 2023.

At sea basin level, the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) already included lead and lead compounds in the OSPAR list of chemicals for priority action in 1998 (OSPAR 2009).

Furthermore, at the Benelux Inter-Parliamentary Council of 20 June 2014, a recommendation was adopted on restricting the use of environmentally harmful substances in fishing and promoting environmentally friendly alternatives.

2.2.1.1 ECHA lead restriction proposal

The European Chemicals Agency (ECHA) is currently developing a proposal for further EU-wide restrictions on the use of lead in hunting ammunition and fishing (ECHA 2021). The proposal aims to address the risks of lead in these activities to protect human health, wildlife and the environment.

The current restriction proposal aims to ban the sale and use of lead in hunting and angling activities in the EU. This proposal is currently subject to a public consultation (24 March - 24 September 2021) and will be scrutinised by the Risk Assessment Committee (RAC) and the Socio-Economic Analysis Committee (SEAC) in autumn 2021. The final advice to Member States (and vote) is foreseen in autumn 2022, with the aim to have the European legal framework adopted in spring 2023 (see ECHA-website for tentative timing).

Specifically, ECHA proposes to ban the sale and use of lead in fishing weights and lures with a transitional period of three years for weights up to 50 g and five years for weights of 50 g and above. Where lead is intentionally lost (e.g. drop-off techniques), an immediate ban is proposed. These periods start from the moment the European Commission has published the new regulatory framework. The combination of a ban on sale and use of lead sinkers and lead-containing artificial lures forms an important pillar in this. After all, a ban on use only may encourage illegal use, since lead can still be offered by angling shops in such a situation, while a ban focusing solely on sale may lead to more purchases from online shops outside the EU (often without quality guarantees) and an increase in the home-casting of lead, with increasing health risks for the angler and immediate family members, especially children and pregnant women.

2.2.2 Federal and Flemish legal framework

In the Programme of Measures for Belgian Marine Waters (Belgian State 2015) to implement the European Marine Strategy Framework Directive (MSFD - Directive 2008/56/EC), Measure 29D provides for the promotion of alternatives to fishing lead in recreational marine fisheries. This measure contributes to achieving the environmental objectives for MSFD descriptor 8 'Pollutants'. Within the federal context, the Commission for Energy, Environment and Climate of 16 March 2021 (CRABV 55 COM 408 (question 5014057C)) considered that phasing out the use of fishing lead should be part of the renewed programme of measures that will come into force from 2022. The federal Marine Litter Action Plan (Belgian State 2017) states that, by analogy with the measure mentioned above, it will also promote the introduction of lead-free alternatives. The updated Plan of Action (in preparation - 2021) also mentions new actions aimed at phasing out the use of fishing lead within a Green Deal context.

In accordance with the Flemish Water Code (Title 3 - Chapter 2 - Article 3.2.1), it is currently forbidden to throw or deposit objects or substances in the waters of the public hydrographic network or in public sewers, to discharge contaminated or polluting liquids or to introduce gases (provided that a permit is issued). In this context, VLAREM II (Annex 2.3.1 'Basic environmental quality standards for surface water'; Article 3§4) categorises lead as a priority substance [PS] (cf. Directive 2013/39/EU), and states that for all priority substances, measures must be taken aimed at their progressive reduction, in accordance with the Decree of 18 July 2003 on integrated water policy. The strict interpretation of the above-mentioned legal framework therefore implies that the (intentional) discharge of lead into Flemish surface water bodies (inland waters) without a prior permit application is a violation of the Flemish law. The use of fishing lead in the context of (recreational) angling is therefore incompatible with the applicable water legislation and requires measures.

Furthermore, at the Flemish level, on 16 March 2016, the Resolution 'concerning the limitation of the use of environmentally harmful substances in recreational angling and the promotion of environmentally friendly alternatives' was signed, with the aim of promoting eco-friendly alternatives in recreational angling and to raise awareness among all actors involved about the harmful effects related to the use of lead sinkers. Following this resolution, since 2019 a so-called sensitising 'Code Lead Use' is included on the Flemish fishing permit and in the Public Fishing Regulations, which states that lead is a toxic metal and calls for the use of lead-free alternatives. In hunting, on the other hand, the use of lead and zinc shot has been completely forbidden in Flanders since 30 June 2008, as stipulated by the Decree of 28 October 1987 of the Flemish Executive concerning the use of firearms and ammunition in hunting in the Flemish Region. This ban was confirmed by the Decree of the Flemish Government of 25 April 2014 regarding the conditions under which hunting can be practised (Art. 10), which provides for the repeal/replacement of the Decree of 28 October 1987. On 11 September 2020, Minister Demir stated in the Flemish Parliament (written question no. 1002) that she is in favour of a European approach to the lead issue, as she believes that a Flemish approach will offer little incentive for angling manufacturers to develop and produce alternatives (see also **3.6**).

2.2.3 Foreign context

At present, within the EU, only Denmark has a ban on the import and sale (not the use) of fishing lead (>0.1% w/w lead) for both commercial and recreational purposes, based on the 'Lead Act' of 13 November 2000. Local bans also apply in a number of rivers and lakes in Sweden (ECHA 2021). In the Netherlands, the Green Deal 222 'Sportvisserij loodvrij' has been implemented since 2018, with the aim of reducing lead use in recreational fishing by 30% by 2021 and phasing it out completely by 2027. However, the Green Deal regulations are not legally enforceable. An evaluation of the preliminary results is scheduled for 2021.

Some other countries, such as the United Kingdom, have bans on certain classes of lead weights. For example, on 1 January 1987, the import and sale of lead weights between 0.06 and 28.35 g was banned in the UK under the Control of Pollution (Anglers' Lead Weights) Regulations 1986. In addition, 'the use' of these weights was also banned by law in England and Wales.

In 1994, the United States Environmental Protection Agency (US EPA) issued a national ban on the production, import and sale of lead and zinc fishing weights smaller than 25.4 mm. However, this ban has not been ratified. Nevertheless, certain States (Maine, Massachusetts, New Hampshire, Vermont, New York) have themselves imposed restrictions on the sale and use of lead sinkers (Michael 2006). A ban on lead weights also applies to some federal territories with swan and duck populations (Franson et al. 2003, Michael 2006, Barnett et al. 2008).

In Canada, the use of lead fishing weights (containing >1% w/w lead) is only restricted within national parks. For example, the use of lead sinkers or jigs weighing less than 50 g is prohibited by the National Parks of Canada Fishing Regulation and the Wildlife Area Regulations. Recently, a study was published by the Environment and Climate Change Canada (ECCC) to map the use patterns of lead weights and their alternatives aiming for a national phase-out (ECCC 2018).

2.3 Lead impact

2.3.1 Impact on human health

Inhalation and ingestion are the main ways of human intake (Hoffman et al. 1995). After ingestion, approximately 5 to 15% of the lead is absorbed, whereas children show a higher intestinal absorption of 40 to 50%. Inhalation of lead-containing vapours or dust results in an absorption of 10-30% of inhaled lead (Hegger et al. 1992, Flomenbaum et al. 2006). After resorption, lead enters the blood (1-4%), soft tissue (2-10%) and compact bone (90-95%). The half-life of lead in blood is about 35 days, in soft tissue it is 1-2 months. In bone this increases to 20-30 years (Hegger et al. 1992).

Young children and pregnant women absorb four to five times more lead than adults (with the exception of pregnant women), making them much more susceptible to the harmful effects of lead (WHO 2010). Most studies on the effects of lead on human health show that even very low levels of lead exposure can have serious and irreversible effects on brain function in children. For example, elevated blood lead levels (BPb) are associated with reduced intelligence (IQ), learning disabilities and behavioural problems (ADHD) (e.g. Canfield et al. 2003, Lanphear et al., 2005, Caravanos et al. 2013, Skerfving et al. 2015, Choi et al. 2016, Alvarez-Ortega et al. 2017, Reuben et al. 2017, Barg et al. 2018, Ji et al. 2018, Wu et al. 2018). Hearing problems and growth retardation are also observed (Schroeder 2010). Blood lead levels above 60 mg/dl are often associated with acute symptomatic conditions, including abdominal colic, anaemia, encephalopathy, epileptic seizures, coma and death (Lanphear 1998). As lower level lead poisoning (10-120 µg/dl) often occurs without clear symptoms (symptoms are often wrongly attributed to other causes), it stays often undiagnosed and hence remains untreated, meaning that no preventive measures are taken (Schroeder 2010). Nevertheless, negative effects on the IQ of young children were already demonstrated by Canfield et al. (2003) at lead concentrations <10 µg/dl.

Sahmel et al. (2015) showed that after hand contact with fishing lead the average transfer efficiency of lead particles to saliva is 24% (range 12-34%), which makes ingestion via hand-to-mouth contact very plausible. However, the greatest risk of lead ingestion occurs during home-casting of lead (inhalation and ingestion) and during angling itself (ingestion through hand-to-mouth contact). In the mid 1990s, home-casting of lead accounted for one third of the total fishing lead production in the USA (Scheuhammer and Norris 1995). No data are available for Belgium. During home-casting of lead, harmful lead particles or vapours may be released into the air. Such lead particles may be inhaled directly or may end up on hands, clothes, floors and carpets, which means that the risks for family members are not limited to the time and immediate location of the actual production (e.g. U.S. Environmental Protection Agency 1994, Washington State Department of Ecology en Washington State Department of Health 2009).

2.3.2 Impact on fauna and flora

Lost fishing lead can remain relatively stable for decades, so that lead particles are not immediately released into the aquatic environment (e.g. Tylecote 1983). In its solid form, metallic lead is not harmful to the environment. However, under certain environmental conditions (e.g. slightly acidic water, acidic soil) lead can weather, mainly through oxidation (Klein en Vink 2013), and dissolved lead particles can be mobilised. These can then be taken up by various plant and animal species whereby biochemical, neurological and physiological effects are documented at certain life stages, and in the case of animals also behavioural effects are reported (see e.g. Rattner et al. 2008, Haig et al. 2014).

The sharp decline of mute swan (*Cygnus olor*) populations in the United Kingdom in the 1970s was attributed to the use of fishing lead (e.g. Goode 1981, French 1984, Sears 1988, Rattner et al. 2008) and resulted in an increasing awareness of the environmental risks associated with lead fishing weights (see also **2.2.3**). Also in Canada and the United States, the effects of these weights on the Great Northern Diver (*Gavia immer*) as well as other bird species have been widely documented (e.g. Pokras en Chafel 1992, Stone en Okoniewski 2001, Sidor et al. 2003, Franson et al. 2003, Haig et al. 2014). Waterbirds ingest lead fishing weights and mistake them for food or grit, which helps them to grind food in the gizzard for better digestion. Once a lead weight enters the gizzard and is ground, the lead is released into the blood.

Where there are legal restrictions on the use of certain classes of lead weights, these seem to to have positive effects from a bird conservation perspective. In England and Wales, there has been a significant reduction in the proportion of swans examined that die as a result of lead poisoning. Between 1971 and 1986, 34% of the animals examined died from lead poisoning, while between 1987 and 2014 this number reduced to 6% (Wood et al. 2019).

Despite the fact that publications on the environmental impact of fishing lead often focus on (or are limited to) waterfowl (i.e. ingestion), the negative environmental impact of lead has also been demonstrated for other species groups that play an important role in the aquatic ecosystem, such as bivalves, amphipods, water fleas, benthic invertebrates, seaweeds, etc. (Hoffman et al., 2000, Besser et al., 2009, Marasinghe Wadige et al., 2014, Søndergaard et al. 2011). Furthermore, Josefson et al. (2008) observed changes in the composition of the benthic fauna in response to submarine deposition of residues from a lead-zinc mine in a western Greenland fjord system (see also Søndergaard et al. 2011). Re-colonisation of the fauna, 15 years after the mine closure, was slow and the affected areas were still dominated by opportunistic species.

All this calls into question the rather arbitrary distinction between the phase-out periods for lead weights <50 g (3 years) and >50 g (5 years) within the European restriction proposal (ECHA 2021). This distinction is based purely on the impact of smaller fishing weights on waterbirds and takes little account of the broader environmental impact of larger weights.

2.3.3 Impact on the environment

Besides the fact that lead is often mistaken by animals for food, lead can also chemically contaminate surface water and soil, posing a potential threat to the aquatic environment and its organisms (see also **2.3.2**). As mentioned above, lead is relatively resistant to corrosion (Tylecote 1983), but can weather under certain environmental conditions, with oxidation being the main dissolution process (Klein and Vink 2013). Consequently, the solubility of lead is highly variable and depends on the prevailing environmental conditions.

Jacks et al. (2001) studied the solubility of lead in natural (freshwater) conditions where a higher solubility (up to 27.1 $mg/cm^2/year$) was detected at higher flow velocities, due to the increased supply of oxygen and the abrasive action of suspension material. Of course, it cannot be excluded that fishing lead becomes buried in the sediment of the water bed, where it will not oxidise and remain stable under reducing bottom conditions. The solubility of lead in seawater has been investigated by only a few studies to date (Krauskopf 1956, Azim et al. 1973, Tylecote 1983, Savenko and Shatalov 2000, Angel et al. 2016). Although the presence of salt accelerates the oxidation rates of most metals, a lower corrosion rate is detected for lead in seawater compared to tap water due to the presence of both chloride and sulphate, resulting in the formation of a corrosion protective film that inhibits lead oxidation (Xie and Giammar 2011). These findings are confirmed by measurements on archaeological finds of lead musket and pistol bullets (Campbell and Mills 1977) that had been exposed to seawater for long periods. On the other hand, the presence of natural organic material (tested with potable water) appears to increase the corrosion rate by inhibiting the formation of an oxidation layer (Korshin et al. 2000). For the marine environment, a corrosion rate for fishing lead between 1.6 and 2.7 $mg/cm^2/year$ was assumed by Klein and Vink (2013) .

In VLAREM II - Annex 2.3.1, basic environmental quality standards are defined for Flemish surface waters (rivers, lakes and transitional waters), including heavy metals such as lead. The annual average environmental quality standard for lead is set at a bioavailable concentration of 1,2 µg/l for rivers/lakes and 1,3 µg/l for transitional waters (estuaries). For lead, almost no exceedances of standards were detected in the monitored freshwater bodies in the period 2010-2019. The greatest number of exceedances were reported for cobalt (53% on average) and zinc (10% on average) (www.milieurapport.be).

Dissolved lead concentrations in marine waters typically vary between 1 and 36 ng/L in the open ocean (Pilson 1998) and between 50 and 300 ng/L in coastal waters influenced by anthropogenic activities (Davis 1993). For the monitoring of lead in the marine environment, water is not the most relevant medium, therefore concentrations in Belgium are measured in biota and sediments (Belgian State 2018). To assess against environmental standards, lead concentrations in sediment are normalised with the content of aluminium (Al) after analysis of the fine fraction (<63 µm) (OSPAR 2015). In the marine sediments, the maximum allowable lead concentration is exceeded at 9 out of 10 monitoring sites (cf. OSPAR, i.e. Effects Range-Low

(ERL) = 47 µg/g dry weight), while the Background Assessment Concentrations (BAC = 38 µg/g dry weight) are exceeded at all sites (Belgian State 2018). The highest lead concentrations, normalised with respect to Al, are found far from the coast (between 149 and 1,160 µg/g). However, measured lead concentrations at the scale of the Southern North Sea in the period 1995-2015 are characterised by a decreasing trend (OSPAR 2017). An increased presence of fishing lead can be found at popular shipwreck sites that act as biodiversity hotspots. For example, in 2018-2019 one tonne of fishing lead was removed on and around the shipwreck 'Westhinder' (Jorens 2019). In biota, on the other hand, lead concentrations are below the predefined maximum values, for which the European Commission has set the limit at 500 µg/kg wet weight (mussels 207 to 320 µg/kg and flounder 29 µg/kg). Lead contamination in fish species consumed by humans also complies with the European maximum values, as stated in Regulation (EC) No 1881/2006 (bony fishes <20 µg/kg (EU max 300 µg/kg); brown shrimp 7 µg/kg (EU max 500 µg/kg); scallops 27-88 µg/kg (EU max 1,500 µg/kg)) (Belgian State 2018).

3. Lead and lead-free alternatives in angling

3.1 Lead application in angling

There are three applications of fishing lead in angling. Lead is used as casting weight, as weighting or as (part of) a lure:

- Casting weight: With the help of casting weights, the angler is able to cast the bait over a certain distance and to deliver it to the desired location and, if desired, keep it there (e.g. anchor weights).
- Lead: A tool used to present the bait lines with hook baits at a desired depth (e.g. lead cannonball, in-line lead, herring lead), whereby the shape and weight are also determined by the prevailing current. Lead can also be used to weight down feeders.
- Lures: A distinction can be made between lures that consist entirely of lead and those where lead forms a part of the product. In the first case, the lead is cast in a form that imitates a baitfish or other natural bait. These are available in various shapes, weights and colours and are fitted with one or more hooks (e.g. pilkers). On the other hand, lead can also be part of a composite lure, such as shads and twisters. Here, lead acts as a tool (e.g. jig head = hook with weighting) to present a lure at the desired depth and to give it the desired movement.

There are many types, shapes and weights in circulation. The type of fishing weight is determined by the intended target species, the fishing equipment (rig) used and the environmental conditions (wind, current, bottom substrate) at the fishing location.

3.2 Causes for lead loss

Lead may enter the aquatic environment through angling for a number of reasons. For example, a line breakage may occur during fishing. This may be due to the line rubbing against the bottom or against an obstacle, exceeding the tensile strength of the material, snagging behind an obstacle, the quality of the line, line breakage at the knot (e.g. when casting heavily), etc. Although line breakage occurs with all types of line, as a general rule a nylon line is less likely to break than a braided line due to its higher elasticity and better resistance to abrasion, although with nylon you must take into account a reduced tensile strength of the material and a less fine registration of the bait.

In addition to unintentional lead loss through line breakage, intentional lead loss also occurs through the lead clip or drop-off system. This system is often used in carp fishing and allows the lead to be intentionally dropped as soon as the fish picks up the rig. This system is used for several reasons:

- To prevent the carp from using the lead weight to unhook itself by shaking its head;
- The lead is said to make landing the carp more difficult;
- The system allows the fish to be drilled more effectively out of a weedy area.

3.3 Estimated annual lead loss in Belgium

In Belgium, approximately 130,000 fishing permits were issued for national public inland waters in 2019, of which about 67,500 for Flanders, 62,500 for Wallonia and 1,400 for Brussels (ANB 2021). The public inland waters comprise all waters subject to river fishing legislation: i.e. all rivers, canals, brooks and connecting waters. In addition, there are isolated ponds where river fishing legislation does not apply and where many private angling clubs are active. No precise figures are known about the number of anglers in such waters, but they may number several tens of thousands.

In 2020, no less than 30% more fishing licences were issued than in 2019. This is probably directly related to the Corona pandemic, with angling gaining importance as an individual outdoor activity or form of nature experience. In recent years, there has also been a rejuvenation of the angling public, with a pronounced increase in the age category of 16 to 30 years (ANB 2021).

In addition, there are around 2,200 anglers active at sea, although this is probably an underestimation. After all, sea angling does not require a licence or permit, therefore the numbers are estimated within the framework of the Belgian monitoring programme for marine recreational fishing (Verleye et al. 2019).

For Belgium, there are no data available on the loss of lead by recreational anglers. In the Netherlands, an estimate was made by Klein and Vink (2013), who estimated the average annual lead loss in the Netherlands per recreational angler to be 60 g for freshwater and 1 kg for marine fishing. In the more recent study by van der Hammen (2019), these values were adjusted to 7 and 43 g respectively. After consultation with national experts in both marine and freshwater angling, and in analogy with the decision of ECHA (2021), it was concluded that the updated values from 2019 were not realistic. Therefore, it was decided to continue to use the values as communicated by Klein and Vink (2013) as the standard. Taking this into account, the total annual lead loss in Belgian public inland waters is estimated at 7.8 tonnes (4 tonnes in Flanders; 3.8 tonnes in Wallonia; <0.1 tonnes in Brussels), while for recreational angling at sea it is about 2.2 tonnes. This brings the estimated total lead loss on public Belgian territory to about 10 tonnes annually. If the average lead loss per fisherman calculated by ECHA (2021) is taken into account (130 g per fisherman), the total annual lead loss in Belgium is about 17.4 tonnes. The real estimate of lead loss is probably even higher, since the lead loss of anglers active in private fishing ponds is not considered here.

3.4 Current use of lead-free angling weights

To this day, lead is by far the most commonly used type of fishing weight in recreational angling. The Dutch study by van der Hammen (2019) shows that 80% of freshwater anglers use lead, while on saltwater this increases to 85%. In Belgium, 94% appear to fish mainly with traditional lead, half of which claim to use 'only' lead, while the other half alternate lead use with alternatives (see table 1 for the alternatives used in Belgium and the Netherlands). This is in contrast to the fact that 98% state that they are aware of the toxicity of lead and 65% believe that environmentally friendly fishing weights should become the norm in the future (Verleye and Devriese 2019). These data suggest that a voluntary programme is unlikely to be effective unless anglers are convinced that lead-free products will provide a significant benefit to their sport and consider the higher costs associated with non-toxic alternatives to be reasonable in light of the achievable benefits. This is closely in line with previous studies in the UK, Sweden, Denmark, USA, Canada, etc., which show that lead phase-outs based on voluntary and awareness-raising initiatives are not effective (see, among others, Thomas 1997, LPC 2012, ECCC 2018, Grade et al. 2019, Wood et al. 2019).

Table 1: Overview of the reported use of lead-free alternatives in Belgium (Verleye and Devriese 2019) and the Netherlands (van der Hammen 2019). The percentages indicate the relative use of a certain type (composition) of weight within the pool of alternatives shown below.

Alternative	Verleye and Devriese (2019)	van der Hammen (2019)	
	Freshwater and marine	Freshwater	Marine
Concrete		<1%	5%
Tin		2%	
Composite	16%		
Glass	4%	32%	
Iron/rebar/steel	20%	14%	30%
Metal*		17%	38%
Stone/boulders	36%	30%	28%
Tungsten	11%	1%	
Zinc/copper/brass	5%	3%	
Other heavy metals	4%		
Other	6%	<1%	

**'Metal' is a generic term and can refer to the use of iron, copper, zinc, tin, etc. It can also include alloys such as steel (iron and carbon) and brass (copper and zinc).*

3.5 Composition of lead-free alternatives

There are many different types of alternatives in circulation, i.e. in various materials, shapes and weights. However, not all alternatives appear to be harmless to the environment. To date, however, there is no international agreement on the standards and chemical compositions of lead-free products, and there can be no intention of allowing alternative (potentially) hazardous substances to accumulate in the aquatic or marine environment after the lead phase-out. Only the United States and Canada have national legislation stating that candidate lead-free bullets, specifically intended for hunting waterbirds and coots, must be subjected to scientific testing to estimate toxicity to animals and ecosystems (USFWS 1997, USFWS 2013). No binding rules for alternative fishing weights have been developed in any country (Thomas 2019). In Belgium, when there are doubts about the impact of certain substances on the aquatic/marine environment or human health, the precautionary principle should preferably be applied or further specific research should provide a definite answer.

3.5.1 Coating

Some fishermen are experimenting with powder coating, applied under heat, around the lead sinkers. However, this technique does not appear to be resistant to mechanical weathering, which means that, in addition to lead, microplastics may also end up in the environment (Verleye and De Rijcke 2018). Alternative coatings (plastic, non-toxic metal, other) were also applied to lead bullets to prevent lead absorption after ingestion by aquatic organisms, but these also proved unsuccessful (USFWS 1986, Thomas et al. 2015, Friend et al. 2019, Grade et al. 2019). **Consequently, coating around lead sinkers in any form is strongly discouraged.**

3.5.2 Heavy metals

In addition, other heavy metals such as zinc, copper (including brass), bismuth, tin and even lead are often found in lead-free alternatives. **Zinc** in particular (7.2 g/cm^3; melting point 419.5°C) appears to be a common metal for incorporation in lead-free alternatives (Modified Materials 2018). However, zinc concentrations already exceed the permitted standard in 10% of the monitored Flemish inland waters (2010-2019) (see **2.3.3**) (www.milieurapport.be). In marine sediments, zinc concentrations have been found to exceed the allowed concentrations in 90% of the monitored locations (Belgian State 2018). A comprehensive risk assessment report on zinc was commissioned by the Joint Research Centre (JRC) of the European Commission (Munn et al. 2010). On this basis, zinc is considered a highly toxic element for aquatic organisms with long-term effects (https://echa.europa.eu/nl/substance-information/-/substanceinfo/100.028.341). Levengood et al. (1999) and Levengood et al. (2000) demonstrated the toxicity of zinc in waterfowl after ingestion. Consequently, the same principle can be expected with fishing weights made from zinc. Furthermore, Fäth et al. (2018) pointed out the high leaching values of commercial zinc shot (also applicable to fishing weights) in the aquatic environment with a negative impact on the water flea *Daphnia magna*. **Therefore, fishing weights with zinc as the main component are considered undesirable and it is proposed to only allow its use as an alloy** (see below) (see also Thomas 2018).

Copper (8.96 g/cm^3; melting point 1,085°C) is a potential alternative to lead fishing weights. However, many copper compounds and complexes are water soluble. In surface waters, copper attaches itself to suspended material or behaves as a free ion, as a result of which copper can migrate over considerable distances (Peeters 2013). In the Flemish water bodies (rivers and lakes), almost no exceedances of standards for copper were found between 2010 and 2019, with the exception of 0.5% of the number of monitoring points in the years 2010 and 2018 (www.milieurapport.be). In marine sediments, on the other hand, copper concentrations were found to be above the standard in 80% of the monitoring sites (Belgian State 2018). When copper enters the soil, it binds strongly to organic matter and minerals. As a result, the transport of copper through the soil is very slow (Peeters 2013). Solomon (2009) provides a brief overview of the impact of elevated copper concentrations in aquatic environments on the organisms living in it, and states that these can affect individual organisms, populations and entire ecosystems. The presence of dissolved organic matter in the water column may offer some protection, as copper binds to it and forms complexes, which reduces its bioavailability. In addition, Fäth et al. (2018) pointed out the high leaching values of commercial copper scrap (also applicable to fishing weights) in the aquatic environment with a negative impact on the water flea *Daphnia magna*. For humans, copper has a rather low toxicity (Peeters 2013, ECHA 2021).

Brass is an alloy of 95% copper and 5% zinc. The copper reduces the mobility of zinc in freshwater environments (Thomas et al. 2007, Thomas and McGill 2008). Brass may contain lead as an impurity, or the latter may be intentionally added to make it more corrosion-resistant (ECHA 2021). Brass can be recycled an infinite number of times without losing its chemical and physical properties, and has lower carbon emissions during this process compared to steel recycling (www.copper.org). However, in many cases recycling is not an option as the lost components are often dispersed in the environment. Furthermore, alloys of copper and tin (12%) are made, resulting in bronze, which reduces the mobility of copper in acidic aquatic environments (Thomas et al. 2007, Thomas and McGill 2008). This reduction in mobility results in a greatly reduced risk of adverse environmental effects and poisoning of animals that ingest them when using brass or bronze. **Therefore, brass and bronze can be considered as possible alternatives to lead fishing weights, although caution should be exercised. On the other hand, pure copper should be discouraged.**

Bismuth (9.8 g/cm^3; melting point 271 °C) is the least toxic element within the group of heavy metals. However, this element is never used purely as an alternative to lead weights, but is always alloyed with 3-6% tin to reduce the brittleness of bismuth (Thomas 2019). Based on the ecotoxicological analysis by ECHA, no environmental classification for bismuth is required as no acute toxicity was observed in fish, invertebrates and algae at a concentration of >100 mg Bi/L (https://echa.europa.eu/nl/registration-dossier/-/registered-dossier/14679/6/1). The absence of toxic effects on a bacterium, an alga, an arthropod and a fish, in bismuth-catalysed coatings, was also demonstrated by Pretti et al. (2013). Furthermore, studies by Kraabel et al. (1996), Sanderson et al. (1997) and Sanderson et al. (1998) did not reveal any toxic effects after implantation of bullets from tungsten-bismuth-tin and bismuth-tin alloys, respectively, in ducks. After implantation of bismuth-tin alloys in mice, mobilisation of bismuth in the following months was observed by Pamphlett et al. (2000) and Stoltenberg et al. (2003). Although no negative effects were observed on the animals in question, the authors urged caution with regard to bismuth. In addition, the Canadian study by Omouri et al. (2017) shows that bismuth added as Bi-citrate in natural sandy soil was toxic to the earthworm *Eisenia andrei*, resulting in a sharp increase in mortality rate. **Consequently, it is recommended to use this element with caution due to the limited (and ambiguous) information available on its ecotoxicity. Additional short-term follow-up studies are strongly encouraged, based on which further decisions concerning the use of bismuth in angling can be adjusted.**

Bismuth is obtained from the refining of metals and is therefore quickly contaminated with lead, unless only high quality products are used. Kanstrup (2012) showed that bismuth-tin bullets contain up to 0.68% (6,800 ppm) of lead. Therefore, high quality bismuth should always be used to minimise lead contamination.

In addition to the above-mentioned elements and compositions, traces of cobalt, antimony and cadmium have also been found in analysed lead-free fishing weights (e.g. Modified Materials 2018, Grade et al. 2019). Since **cobalt** exceeded by far the most standards in Flemish surface waters in the period 2010-2019 (on average in 53% of the monitoring sites; www.milieurapport.be), a further influx of this element should be **avoided** in the future. Cobalt impurities in tungsten, for example, may not exceed the norm values as mentioned under **3.5.5**. Weights that use **antimony** as a by-product, with maximum recorded concentrations of 4% (Modified Materials 2018), should be **banned** regardless of the concentrations in view of the genuine toxic effects on the environment (e.g. He et al. 2019) and the non-existent need for integration in fishing weights. For **cadmium**, a comprehensive overview of the available scientific knowledge and the toxicological effects on humans, fauna and flora is given in UNEP (2010). The available data shows that cadmium bioaccumulates in all levels of the food chain. This report also stresses the importance of reducing or eliminating anthropogenic cadmium influx into the environment. Since it is by no means an essential element for fishing weights, it is suggested that cadmium should **not** be **allowed** in lead-free alternatives regardless of the concentration.

3.5.3 Other metals

Pure **tin** (5.77 g/cm³; melting point 232 °C) is already used for small fishing weights, where the high degree of malleability allows the weight to be repeatedly clamped onto the fishing line. While elementary tin and the inorganic tin compounds are considered relatively non-toxic to any organism, the organic tin species exhibit a number of different toxic reactions (Dopp en Rettenmeier 2013). The latter appear to be very persistent and non-biodegradable, and are highly toxic to fungi, algae and phytoplankton (e.g. Fent 1996, Gajda en Jancsó 2010). **Based on this, it is advised not to allow fishing weights consisting mainly of tin, and to only allow tin as an alloy.**

Tungsten (19.3 g/cm³; melting point: 3,422 °C), or better tungsten alloys, are proving successful from a functional perspective in replacing lead sinkers. They are harder than lead, and due to their higher mass density, fishing weights can be reduced in size. Tungsten is also available in powder form. In this way, tungsten can be mixed with a soft polymer putty that can be squeezed around the fishing line (including reuse) or it can be mixed with a hard high-density plastic polymer (polyethylene; HDPE) and produced in the desired shape using thermoforming technology. However, the latter technique is not compatible with the European strategy on the reduction of the impact of certain plastic products on the (aquatic) environment and human health, cf. Directive (EU) 2019/904. This directive also provides for an extended producer responsibility and states that the disposal costs for the listed single-use plastic products must be borne by the producers in question. Furthermore, mixing tungsten powder with HDPE prevents the recycling of the latter, which goes against the European strategy for plastics in a circular economy (COM (2018) 28). In addition, irrespective of the recycling potential, most of the lost fishing weights remain in the aquatic or marine environment. The gradual degradation can then result in the release of microplastics (see also Devriese and Janssen 2021). Therefore, research into the use of biocomposites to manufacture fishing weights is strongly encouraged.

Thomas (2015) urged caution in distinguishing tungsten alloys from tungsten metal (elemental W), and chemical tungsten compounds, in terms of determining toxicity. Often alloys with cobalt or nickel are deliberately made to provide the tungsten alloy with the desired properties. However, it appears that it is probably the cobalt and nickel ions that are the driving force behind the observed toxicity and carcinogenicity of tungsten alloys (Verma et al. 2011, Wasel and Freeman 2018). Tungsten is currently not listed or classified as a carcinogen, while the International Agency for Research on Cancer (IARC) and ECHA-REACH, among others, describe cobalt and nickel as highly toxic and carcinogenic. As with bismuth, the purity of the initial product in question should be noted. Tungsten is available as a highly refined product, but also as a commercial waste product that already contains nickel. From this point of view, it is paramount to unambiguously determine the maximum allowed concentration of toxic by-products in tungsten, whereby Thomas (2018) considers a maximum contamination standard of 1% for nickel to be feasable from a production perspective.

Pure tungsten has so far not been shown to exhibit carcinogenic properties when ingested or embedded in animal tissue (Thomas et al. 2009). On the other hand, the study by Inouye et al. (2009) showed that sodium tungstate (Na_2WO_4) exhibited lower acute but higher sublethal toxicity in earthworms compared to lead nitrate ($Pb(NO_3)_2$). Furthermore, tungsten was initially assumed to be immobile in the environment, while recent studies report a movement and trace amounts of tungsten in soil and drinking water sources, increasing the exposure risk for humans (Tuna et al. 2012, ATSDR 2015, Emond et al. 2015, Wasel and Freeman 2018). Correlations have also been identified between the occurrence of tungsten on the one hand and environmental contamination and biological effects on the other, which has led to tungsten often being classified as an 'emerging pollutant' (e.g. Datta et al. 2017). Despite these associations, there is no scientific consensus on the mechanisms by which tungsten impacts the human body and the environment. Indeed, as mentioned above, it is not easy to eliminate the co-toxicity of other pollutants, such as cobalt and nickel, during toxicity analyses (e.g. van der Voet et al. 2007, Datta et al. 2017).

Several environmental safety studies have been published in the peer-review literature, evaluating different types of tungsten-based lead gunshot, such as tungsten-bismuth-tin (Kraabel et al. 1996), tungsten-iron-nickel (Brewer et al. 2003), tungsten-iron and tungsten-polymer (Kelly et al. 1998, Mitchell et al. 2001a, Mitchell et al. 2001b, Mitchell et al. 2001c); and tungsten-copper-tin-iron (tungsten bronze) (Thomas et al. 2007, Thomas en McGill 2008, Thomas et al. 2009). Based on these studies, the US Fish Wildlife Service approved (as of 2 April 2014) ten types of tungsten-based lead shot (table 2).

As the toxicity of pure tungsten has not yet been unambiguously proven scientifically, the use of **tungsten (as a pure element)** as a lead-free alternative can be **provisionally authorised**. In order to use tungsten as a fishing weight, it has to be mixed with other components or elements. **Tungsten alloys with nickel and cobalt should be avoided**. Furthermore, the use of **tungsten powder in combination with HDPE is strongly advised against** and **further research into binding biocomposites is strongly encouraged**. If future scientific research should reveal any toxic properties of pure tungsten, it is recommended that (national) measures be adjusted accordingly.

Iron is abundant in the Earth's crust and occurs naturally in the aquatic environment. It is an essential element for nearly all living organisms (e.g. Xing en Liu 2011). In the presence of water and oxygen, iron forms iron oxide (rust). Alloys can make the metal corrode less quickly. For example, carbon can be added in varying amounts, resulting in **cast iron** or **unalloyed steel**. Steel, meanwhile, is successfully used as a lead substitute in fisheries. These compositions can be **permitted and promoted as lead-free alternatives**. Thermal **galvanised steel** (zinc alloy) is **preferably avoided** and should not be actively promoted due to the toxic properties of increased zinc concentrations. Furthermore, the **addition of zinc** in angling is mainly an **aesthetic motive** (i.e. to avoid rust), which makes the weight more attractive. After all, rust formation in itself does not result in reduced fishing performance (air and current dynamics, camouflage, etc.).

Table 2: Overview of tungsten lead shot approved by the US Fish Wildlife Service (Source: US Fish & Wildlife Service: http://www.fws.gov/birds/bird-enthousiasts/hunting/nontoxic.php).

Approved types of gunshot	Percentage composition by weight
Iron-tungsten	W (variable %); Fe (≥1%)
Tungsten-nickel-iron	Fe (≥1%); W (variable %); Ni (≤40%)
Tungsten-bronze	W (51,1%); Cu (44,4%); Sn (3,9%); Fe (0,6%) of W (60%), Cu (35,1%), Sn (3,9%), Fe (1%)
Tungsten-iron-copper-nickel	W (40-76%); Fe (10-37%); Cu (9-16%); Ni (5-7%)
Tungsten-matrix	W (95,9%); polymer (4,1%)
Tungsten-polymer	W (95,5%); Nylon 6/11 (4,5%)
Tungsten-tin-iron	W (variable %); Sn (variable %); Fe (≥1%)
Tungsten-tin-bismuth	W (variable %); Sn (variable %); Bi (variable %)
Tungsten-tin-iron-nickel	W (65%); Sn (21,8%); Fe (10,4%); Ni (2,8%)
Tungsten-iron-polymer	W (41,5-95,2%); Fe (1,5-52,0%), fluoropolymer (3,5-8,0%)

Stainless steel is high-alloy steel and its purpose is to make the steel corrosion resistant by adding chrome and nickel. The main types of stainless steel are Type 304 (18% chrome; 8% nickel) and Type 316 (16% chrome; 10% nickel; 2% molybdenum). However, despite the fact that stainless steel is stable in freshwater environments (e.g. Thomas 2021), Matsuhashi et al. (2010) showed that in a marine environment all stainless steel types are subject to crevice corrosion over time. However, other natural water types such as brackish water, dune water and spring water can also cause crevice or pit corrosion if they contain chloride (www.alurvs.nl). Oxygen-rich water (e.g. in flowing water) also increases the risk of crevice corrosion at the metal surface. In the case of crevice corrosion, the current can carry away the concentration of chloride ions and the reaction products formed during the breakthrough, after which the surface spontaneously repassivates due to the supply of oxidising substances (oxygen). In addition, cracks and pits may also form under sediments, such as sand and in seawater, as a result of attachment of mussels, barnacles and other biological organisms (e.g. Masatsune et al. 1975).

In Type 304 and 316, the solubility of nickel is greatly reduced by the inclusion of chromium in the alloy. The concerns regarding nickel are mainly related to the toxic effects that this element exerts on organisms that swallow it (e.g. swans, herons). The dissolution of nickel in gastric acid is slow, but real. However, if the excretion rate of nickel from the body is faster than the dissolution process, a toxic situation as such is avoided (Thomas 2021). In order to avoid a potential chromium and nickel influx into the environment, the **use of other approved alternatives is encouraged, but stainless steel may also be retained as an alternative based on the general resistance of the product**. In the marine environment the use of Type 316 is recommended for better resistance to salt corrosion. This seems contradictory at first sight, as the use of stainless steel hooks has already been banned in many regions. However, this prohibition is related to the slower degradation rate of stainless steel hooks compared to unalloyed steel, which gives the fish lower survival rates in case of line breakage or in cases where the hook cannot be removed, and has no toxicity-based reason.

Fish weights based on **iron powder** bound with biopolymers were subjected to a functional practical test in the study by Verleye and Devriese (2019). These weights were rated moderately positive to positive by the test group. As with tungsten powder, the binding of the iron powder should not be done on the basis of an HDPE. The use of iron powder is considered to be an

environmentally friendly alternative, provided that the binding of the powder occurs on the basis of biopolymers/biocomposites. Therefore, also within this context, further **scientific research into suitable biological binding agents is strongly encouraged**.

3.5.4 Other alternatives

On the basis of a survey conducted in the context of the study by Verleye and Devriese (2019), **stones or boulders** appear to be among the most frequently used alternatives and generally score best as lead substitutes. The frequent use of stones (within the context of lead substitutes) also emerges from the Dutch study by van der Hammen (2019). Stones seem to be a popular alternative among carp anglers (ECHA 2021 CfE: Sportvisserij Nederland). Furthermore, stones naturally provide good camouflage. These weights can either be made by the angler or purchased from specialist retailers. Alternative weights based on **minerals** are also available. **The use of stone, mineral and boulder weights as lead-free alternatives is strongly recommended and should be encouraged.**

Like stone, (weighted) **concrete** can also be used as an alternative. This material is a good alternative for a.o. carp fishing. Concrete weights can be weighted with an iron core on the inside. The use of (weighted) **concrete as an alternative is recommended**.

A survey of Dutch freshwater fishermen (van der Hammen 2019) shows that the use of glass is a popular alternative. The Belgian survey (Verleye and Devriese 2019) shows that glass is used less frequently, but users score this alternative high on functionality. As glass does not contain any substances that are harmful to the aquatic environment, the **use of glass is permitted and encouraged** as an alternative.

3.5.5 Summary of desirability of alternatives

Based on the arguments presented (**3.5.1 - 3.5.4**), an overview of the alternative compositions of the fishing weights and under what conditions they may or may not be used is presented in table 3. The assessments of alternative metals are partly based on the findings of Thomas (2018), and were determined based on their availability, density and other physical properties, ease and production cost, and proven non-toxicity to animals under specified conditions.

3.6 Production of alternative fishing weights

Based on input from angling experts and online searches, an overview was made of various producers that are already actively developing lead-free alternatives within their commercial product range (mainly European producers) (table 4). Note that this is not an exhaustive overview. It is remarkable that only two Belgian producers were identified (mainly focus on tungsten). The largest European producing countries are the Netherlands, Germany and the United Kingdom. The international character of the production market for fishing weights once again reflects the added value of an ambitious European approach to lead restrictions (see also Parliamentary question no. 1002). A Belgian ban on the use and/or sale of lead fishing weights alone will probably not be enough to encourage international companies to invest in lead-free alternatives. However, this does not alter the fact that national measures should preferably focus on, and contribute to, the protection of the aquatic environment, the fauna and flora and public health. In addition, it is striking that only one-third of the companies listed in table 4 are focussing exclusively on lead-free alternatives. The remaining companies offer a lead-free product range (of varying degree) in addition to the production of lead fishing weights.

Although only a third of the companies listed are fully dedicated to the development and production of lead-free alternatives, significant amounts of alternative fishing weights, jigs, pilkers/plugs and feeders are already being offered. Please note that not all alternatives are classified as 'environmentally friendly' within the context of this report (see **3.5.5** and table 3). The most common compositions on the supply side are tungsten, stainless steel, stones/concrete and iron. Within the context of lead-free alternatives, the user side is currently using mainly stone (28-36%) and iron/steel (14-30%), while tungsten seems to be comparatively less common (0-11%) (see **3.4**).

Table 3: Overview of the composition of alternative fishing weights and their conditions of use. The assessment of metals was partly based on the conclusions of Thomas (2018).

Component	Degree of desirability	Remarks
Coating		
Plastic/powder coating	No	Functionality failure (incl. microplastics)
Heavy metals		
Antimony (Sb)	No	Toxic and no need to use.
Bismuth-tin (Bi + Sn)	Tolerable	Follow-up studies on the ecotoxicity of bismuth are strongly encouraged. Careful use recommended.
Cadmium (Cd)	No	Toxic and no need to use.
Cobalt (Co)	No (<1% w/w)	Only permitted in very limited concentrations as impurities in alternative metals. Standards already exceeded in 53% of the Flemish freshwater monitoring sites.
Pure copper (Cu)	No	
Brass (Cu + 5% Zn) and bronze (Cu + 12% Sn)	Tolerable	Careful use recommended.
Lead (Pb)	No (<0,1% w/w)	Only permitted in very limited concentrations as impurities in alternative metals.
Nickel (Ni)	No (<1% w/w)	Only permitted in very limited concentrations as impurities in alternative metals. In stainless steel, higher nickel concentrations (~10%) are allowed in combination with chromium, based on the resistance potential.
Zinc (Zn)	No, only acceptable as alloy	Zn should be avoided as the main component in alternative fishing weights. Where thermal galvanising of iron/steel weights is used solely to prevent rust (i.e. as an aesthetic motive), Zn should be avoided, as rust formation in itself does not result in reduced fishing performance. Standards already exceeded in 10% of the Flemish freshwater monitoring sites.

Component	Degree of desirability	Remarks
Other metals		
Iron (Fe) / cast iron / unalloyed steel	Yes	
Iron powder and composite	Yes	Binding with biocomposites/biopolymer. Avoid bonding with HDPE.
Stainless steel	Tolerable	Considered stable in freshwater environments. In the marine environment, Type 316 is recommended (more corrosion resistant). Preference for other more environmentally friendly alternatives.
Tin (Sn)	Only acceptable as alloy	Sn is not desirable as the main component in alternative fishing weights.
Tungsten (W)	Tolerable	All %W w/w permitted. Mixing with other elements or substances is allowed under the conditions mentioned in this table and in 3.5.3, taking into account the latest scientific findings on toxicity. In case of tungsten powder, the binding should be done with biocomposites/ biopolymers and binding with HDPE is not desirable.
Other alternatives		
Concrete	Yes	Can be weighted by means of an iron core.
Glass	Yes	
Stones / boulders/ minerals	Yes	

A shortcoming that frequently occurs on online web shops is the lack of transparency regarding the actual composition of alternative weights. Weights are often described as 'lead-free', 'environmentally friendly' or 'non-toxic', while no information is provided about the actual composition of the product. Also when one tries to obtain information about the products in question on the manufacturers' websites, often no information can be found. Increased transparency regarding the composition of lead-free weights is therefore strongly recommended.

3.6.1 Production capacity of environmentally friendly alternatives

In order to get a first indication of the current production capacity of alternative weights and the required transition period towards lead-free angling, ten companies focusing exclusively on the production of 'environmentally friendly' alternatives were contacted (see table 4 - in bold). This non-binding request for information resulted in seven interviews with entrepreneurs from Germany, the United Kingdom, the Czech Republic and the Netherlands[1].

[1] The interviews were specifically focused on producers who are currently focusing exclusively on environmentally friendly alternatives (i.e. alternatives that consist mainly of natural raw materials that do not cause demonstrable health or environmental problems). The purpose of the questionnaires was to obtain information on the current production capacity, the willingness and conditions to scale up, the necessary investments in case of scaling up, the maximum future production capacity, the necessary transition time for scaling up and the perception of the present phase-out dates, as proposed by ECHA (2021). The following companies have contributed to the present insights: Pallatrax (UK - Simon Pomeroy); Fishstone (D - Karsten Jaszkowiak); Het Juist Vislood (NL - Jib Bazuin); Rockbottom Fishstones (NL - Marc ter Horst); UFO Sinker - Zenergo Holding (CZ - Zdeněk Vavřina); Modified Materials (NL - Egbert and Jos Lobée); Ronny Clijncke (NL - company in formation).

Table 4: Non-exhaustive overview of producers that are fully or partially involved in the production of lead-free fishing weights. Alternatives that are preferable from an environmental point of view and should be encouraged are indicated in bold. Alternatives that do not meet the environmental criteria as defined in this report are marked with an ''.*

Producers	Country	Composition	Alternatives available for	100% focus on alternatives	Types of fisheries (focus)
Ashima	UK	tungsten	putty	no	carp fishing
Behr	DE	tungsten, stainless steel	weights, jigs, plugs/pilkers, putty, feeders	no	sea fishing
Berkley	UK	tungsten	weights, jigs	no	sea fishing, predator fishing
Bidoz	FR	tungsten, brass	beads, verzwaring	yes	fly fishing
Big Fish Tackle (BFT Tackle)	SE	tungsten	weights, jigs	yes	predator fishing
Black Flagg	IT	tungsten	weights, jigs	?	predator fishing
Camo-Tackle	DE	tungsten	weights, jigs	no	predator fishing
Caperlan	UK	steel (?), plastic* (?)	feeders, weights (lead), jigs (lead)	no	carp fishing
Carp whisperer	NL	tungsten	putty	no	carp fishing
Diamond weights	UK	**glass**	weights	yes	
Drop-it Tackle	NL	tungsten	weights, jigs	yes	predator fishing
Evezet	NL	plastic*, stainless steel	feeders	no	whitefish fishing
eXtra Carp Falconi	SRB	galvanised steel, PVC*	feeders	no	whitefish fishing
Faith Carp Tackle	NL	unknown	weights	yes	carp fishing
Fishstone	DE	**stones and toolkit-development**	weights	yes	all types
Fladen	SE	tungsten, zinc*	weights, pilkers	no	sea fishing
Foxrage	BEL	tungsten, brass	weights, pilkers, beads	no	predator fishing, fly fishing
Fred Buzzerd	NL	steel	weights	no	sea fishing; catfish fishing (predator fishing)
Fulling Mill	UK	tungsten, brass	beads, weightening	yes	fly fishing
Hengelsportparadijs	NL	**iron**	weights	no	sea fishing
Het Juiste Vislead	NL	**concrete, iron**	weights	yes	carp fishing, sea fishing
HTO	UK	tungsten	weights, jigs, plugs/pilkers	yes	predator fishing
Illex	FR	zinc*	jigs	no	sea fishing
ImFlo	SRB/NL	steel (type?), **iron**	feeders, floats, splitshot	no	whitefish fishing
Iron Claw	DE	stainless steel	jigs	no	predator fishing
Keitech	USA	tungsten	jigs	yes	predator fishing
Kinetic	DK	zinc*, plastic*	weights, plugs/pilkers	no	sea fishing
Leonard Fishing Tackle	NL	unknown	weights	no	all types
Lucky John	LV	tungsten	jigs, plugs/pilkers	?	predator fishing
Lureparts	NL	tungsten	weights, jigs, plugs/pilkers	no	predator fishing
Major Fish	DE	tungsten, brass	weights	no	predator fishing

Matrix	UK	stainless steel	feeders	no	whitefish fishing
Modified Materials	NL	**composite, mineral, (cast)iron**	weights, jigs, plugs/pilkers, feeders	yes	all types
Pallatrax Stonze	UK	**stones**	weights	yes	carp fishing
Reins	USA	tungsten	weights	yes	predator fishing
Robinson (Carpex Natural Stone)	PL	steel (?), **stones**	feeders, weights	no	whitefish fishing, carp fishing
Rockbottom fishingstones	NL	**stones**	weights	yes	carp fishing
Roto Metals	USA	bismut-tin	weights	no	carp fishing, sea fishing
Rubig Steelangler	DE	steel	weights	yes	carp fishing, sea fishing
Savage gear	DK	tungsten, brass	jigs, weights	no	sea fishing
Spro en Spro Freestyle	DE	tungsten, brass, stainless steel	weights	yes	predator fishing
SuXXes	NL	**stones**	weights	yes (?)	carp fishing
Taska	UK	tungsten	weights	yes	carp fishing
Ultimate	FR	brass, stainless steel, tungsten	weights, jigs, plugs/pilkers	no	sea fishing, predator fishing
UFO Sinker (Zenergo holding)	CZ	**concrete-iron-composite**	weights	yes	carp fishing
UL-Fishing	BEL	**glass** (beads), tungsten	beads, weights	no	predator fishing
Westin	UK	brass	weights	no	predator fishing
WiLDFiSH (former Kinger Fishing lead-free lures)	CA	bismut+tin; stainless steel	jigs	yes	Predator fishing, sea fishing
World Fishing Tackle	DE	tungsten (wire), composite (?)	wire, weights	no	sea fishing
Woutje Concrete	NL	**concrete+iron**	weights	yes	carp fishing, sea fishing
Yuki	ES	**iron**	weights	no	sea fishing
Zebco	DE	tungsten, other (?)	weights, jigs	yes (?)	sea fishing, predator fishing
Zeck Fishing	DE	**concrete**, coating rond leadvrije jigs*	weights, jigs	no	predator fishing (catfish fishing)
Zfish	CZ	steel, tungsten	feeders, putty	no	whitefish fishing

Based on the information obtained, it can be stated that the majority of the companies currently have a limited production capacity, varying between a maximum of 300 and 10,000 pieces per day. This limited capacity can be fully attributed to a limited demand for environmentally friendly alternatives. All companies indicate that a rapid (in theory unlimited) upscaling within a period of two months to a maximum of two years is possible and that a continuous supply of raw materials can be guaranteed. Where manual labour is central, upscaling can easily be achieved by hiring additional staff, possibly linked to investments in new production areas or (where possible) to further automate production processes. The majority is prepared to scale up and make additional investments purely on the basis of an increasing demand or long-term contracts, regardless of whether a legal lead ban comes into force. A scale-up in production capacity can then have a positive effect on pricing. One company suspects that in the event of a lead ban, small-scale companies risk becoming superfluous because large companies will develop plenty of alternatives. In this regard, there is a fear of mass imports from low-wage countries (e.g. China) via the global shipping industry, which would call into question the actual environmental friendliness of the alternatives (ecological footprint). One company awaits a ban on use coupled with enforcement before considering large investments.

The transition period of three (<50 g) to five years (>50 g) envisaged by ECHA, to be counted from the entry into force of the regulation (foreseen in 2023), is perceived as too long by all companies surveyed from a production point of view. In 2015, the EFTTA (European Fishing Tackle Trade Association) already called for the voluntary phasing out of the production, import, sale and use of lead >0.06 g by 2020 at the latest and its replacement with suitable alternatives (EFTTA 2015), but so far little visible efforts have been made by the large-scale angling industry. A new transition period imposes a risk for continued lead production until the effective ban date. It is expected that innovation will take off from the prohibition date. A quick transition is therefore strongly recommended.

3.7 Price analyses

At present, the idea is that the higher prices for lead-free alternatives, in addition to the effectiveness of alternative weights and the often limited supply in angling shops (see also **3.8**), are still an obstacle for many anglers to make the switch to a more environmentally friendly way of fishing. Verleye and Devriese (2019) showed that two out of three fishermen would only switch to environmentally friendly alternatives if the prices were similar to lead. One out of three is prepared to pay more. Whereas only 7% are prepared to pay a higher price for an alternative that does not approach the physical properties of lead (e.g. lower mass density, more resistance), half of them (49%) are of the opinion that they will only voluntarily switch to an environmentally friendly alternative if both the price and the physical properties (i.e. effectiveness) match those of lead. These high demands mean that the few producers who are currently fully committed to the eco-friendly alternatives do so mainly from an idealistic point of view of making fisheries lead-free, while the financial return is still limited.

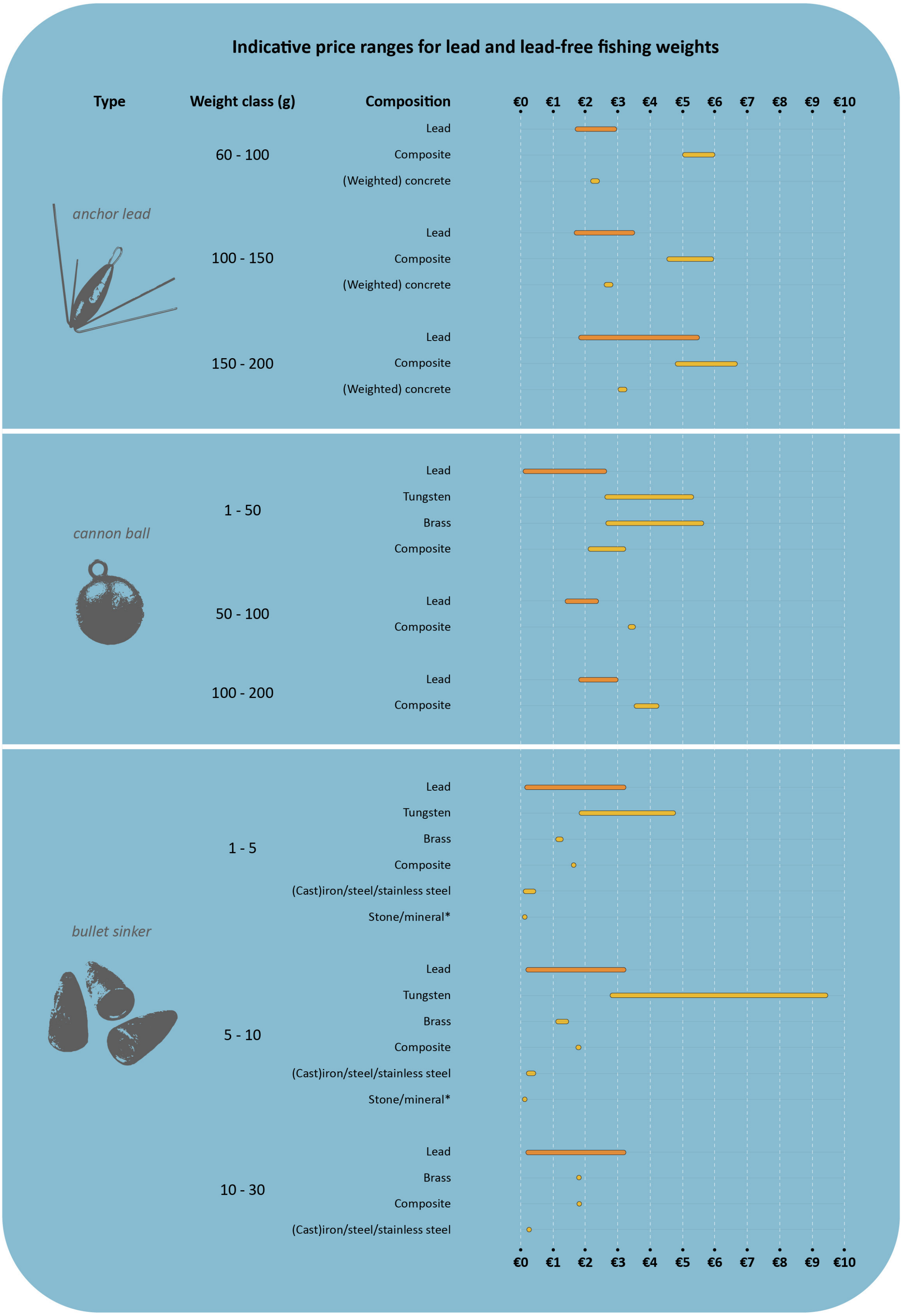
Based on an economic impact study, the purchase of lead-free weights would result in a 3% (€30) increase in the fisherman's average annual fishing related budget (30% increase in average expenditure specifically on weights), and an additional expenditure of €2 per fisherman per fishing day (ECHA 2021). Consequently, the effect of some more expensive environmentally friendly alternatives on total hobby-related expenditure can be described as 'rather limited'.

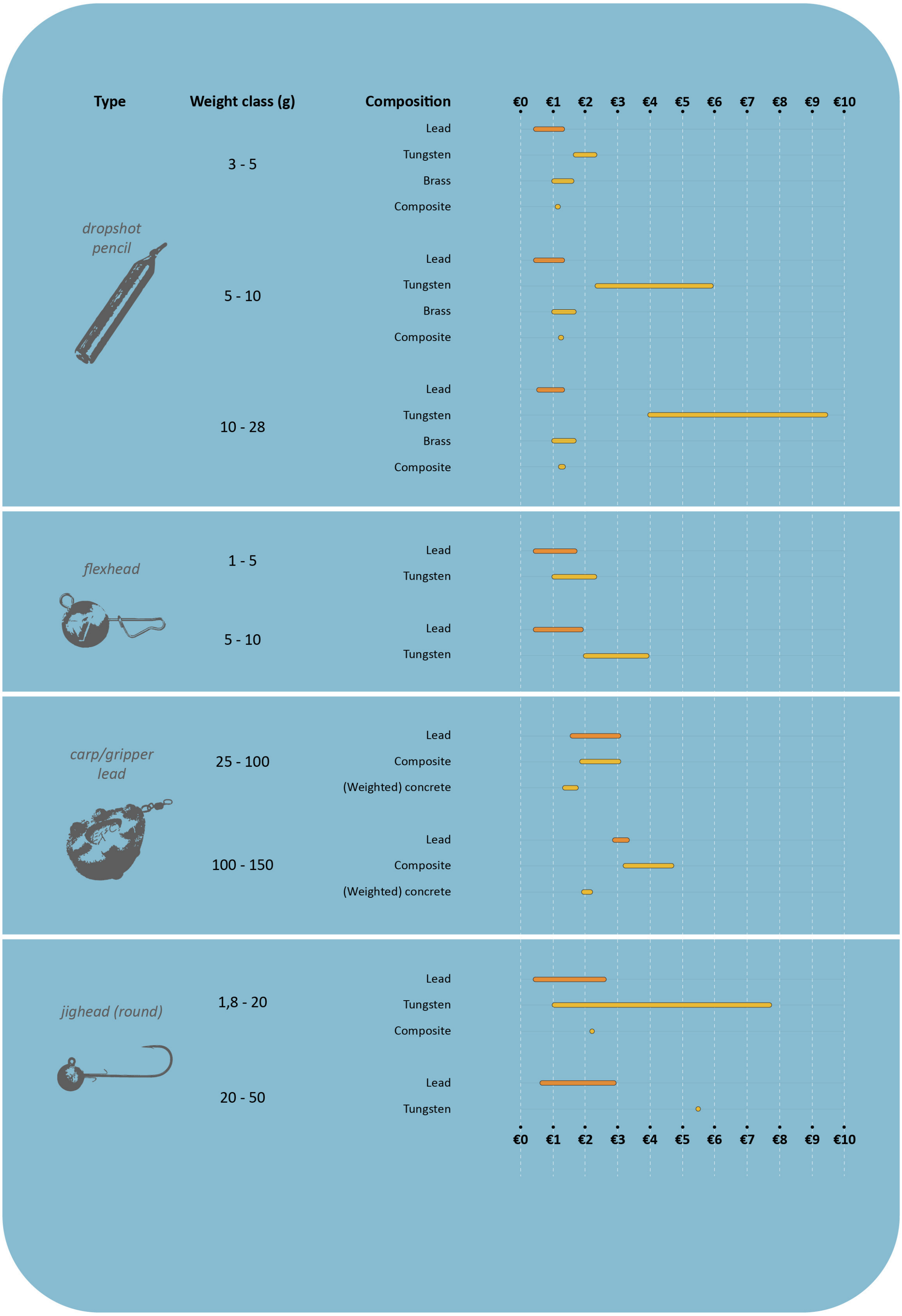
Furthermore, the argument that these alternatives would have a significant budgetary impact is partly invalidated by the fact that losses of lead are currently reported to be minimal. Therefore, both arguments (limited lead loss and budgetary impact) cannot be reconciled. Either there is a negligible loss resulting in a limited budgetary impact, or there is a significant loss with potential impact on expenditure, but in the latter case environmentally friendly alternatives should be recommended even more strongly as the potential environmental impact due to lead loss is then underestimated.

Moreover, in regions with a lead ban there is no evidence that the additional costs for fishermen related to the purchase of alternatives and the possible reduced effectiveness would have a negative impact on participation rates (ECHA 2021). According to a recent US study, the main motives for going fishing are: exercise, being with family and friends and enjoying nature (VS 2018). Consequently, catching fish is not a top priority for the majority of fishermen. This is also confirmed by the European Fishing Tackle Trade Association (EFTTA 2017), who cite relaxation, the creation of social bonds and the enjoyment of the natural environment as the main motivations for going fishing. According to EFTTA, therefore, no significant effects on participation rates are expected in the event of a lead ban.

In order to get an indication of the additional cost of the commercially offered alternative weights compared to the lead weights, a price analysis of mainly Dutch and Belgian web shops was carried out for a selection of weights (see figure 1). For this purpose, the types of weights were subdivided into several weight categories, whereby the price range (minimum vs. maximum price) was analysed for each composition. The prices are purely indicative and should be interpreted with caution, due to the weight variations within each of the predefined weight categories, variations in quality and design and the dynamic character of the pricing in the web shops (discounts, etc.). Nevertheless, the price intervals give a good overall picture of the order of magnitude of the price variations between weights with different compositions. Furthermore, the price survey reveals that a specific composition is often only commercially available for a selection of weight types or classes. Note that the absence of a price indication for certain compositions for a specific weight type is due to the fact that this material type was not found during the price investigation, but does not give any indication as to whether the alternative in question exists or not.

On the basis of the price analysis, it can be stated that the minimum price for lead weights in the majority of cases actually is the cheapest option, despite the fact that the price range is often wide due to the factors mentioned above (weight variations, quality, dynamic prices). Where available, stone and (weighted) concrete, and in the case of bullet sinkers also steel, are alternatives in the same price range, or sometimes even cheaper (figure 1, table 5). Small producers of eco-friendly alternatives nowadays often operate from an idealistic vision about lead-free fishing, and try to charge prices that compete with those of lead. Tungsten is currently by far the most expensive alternative. If the midpoint between the minimum and maximum prices is considered, tungsten costs on average 3.3 times as much as lead, with peaks of over a factor 7. Brass has an average extra cost by a factor of 1.5 (range 0.7 to 3.0), while the extra cost for composite weights is on average 1.6 (range 1.0 to 2.5). For details on the normalised price comparison between lead and alternative weights, see table 5.


Indicative price ranges for lead and lead-free fishing weights
Type
Weight class (g)
Composition
€0 €1 €2 €3 €4 €5 €6 €7 €8 €9 €10
anchor lead
60 - 100
Lead
Composite
(Weighted) concrete
100 - 150
Lead
Composite
(Weighted) concrete
150 - 200
Lead
Composite
(Weighted) concrete
cannon ball
1 - 50
Lead
Tungsten
Brass
Composite
50 - 100
Lead
Composite
100 - 200
Lead
Composite
bullet sinker
1 - 5
Lead
Tungsten
Brass
Composite
(Cast)iron/steel/stainless steel
Stone/mineral*
5 - 10
Lead
Tungsten
Brass
Composite
(Cast)iron/steel/stainless steel
Stone/mineral*
10 - 30
Lead
Brass
Composite
(Cast)iron/steel/stainless steel
€0 €1 €2 €3 €4 €5 €6 €7 €8 €9 €10


Type
Weight class (g)
Composition
€0 €1 €2 €3 €4 €5 €6 €7 €8 €9 €10
dropshot pencil
3 - 5
Lead
Tungsten
Brass
Composite
5 - 10
Lead
Tungsten
Brass
Composite
10 - 28
Lead
Tungsten
Brass
Composite
flexhead
1 - 5
Lead
Tungsten
5 - 10
Lead
Tungsten
carp/gripper lead
25 - 100
Lead
Composite
(Weighted) concrete
100 - 150
Lead
Composite
(Weighted) concrete
jighead (round)
1,8 - 20
Lead
Tungsten
Composite
20 - 50
Lead
Tungsten
€0 €1 €2 €3 €4 €5 €6 €7 €8 €9 €10

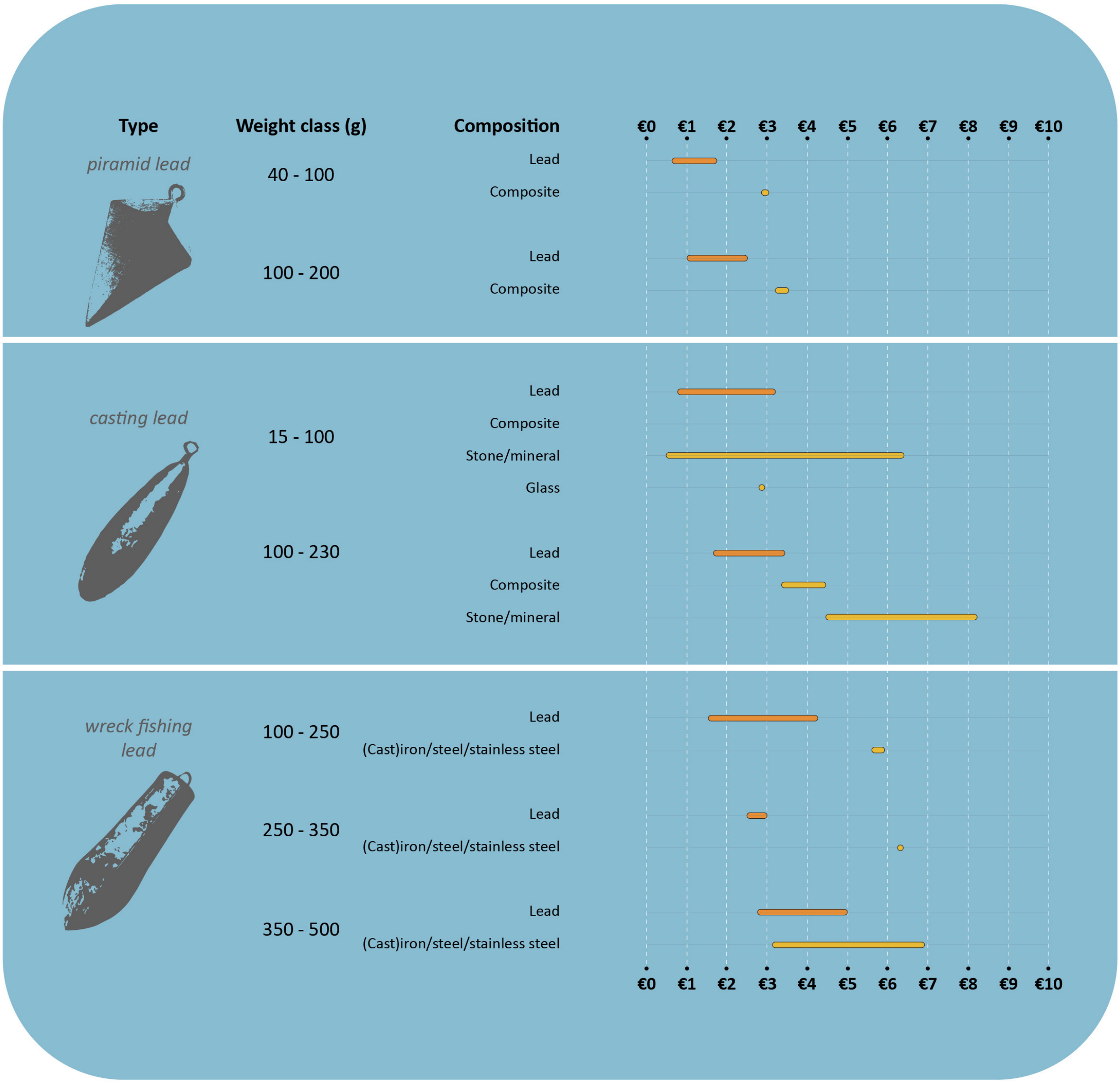


Figure 1: Price categories of a selection of fishing weights (per piece). The prices are purely indicative, due to the weight variations within each weight category, variations in quality and design and the dynamic nature of pricing in (online) shops (discounts, etc.). The prices are primarily obtained from Belgian and Dutch webshops. Significant price reductions such as those found on international web shops like Alibaba, AliExpress, Amazon, etc. are not taken into account here (with the exception of the bullet sinkers, indicated with an '*'). The absence of a price indication for certain compositions for a certain weight refers to the fact that this type of material was not found during the price investigation, but this does not indicate the existence or non-existence of the alternative in question. The websites consulted for price indications are: www.visdeal.nl; www.visdealshop.nl; www.eurotackle.com; www.hetlozevissertje.be; www.ahoywinkelonline.nl; www.deroofvisser.com; www.zunnebeld.nl; www.decathlon.be; www.raven.nl; www.faithcarptackle.com; www.karperxl.nl; www.vislokvoer.nl; www.fishingdirect.nl; www.lured.be; www.hertog-hengelsport.nl; www.loodvrijvissen.nl; www.diamondweights.co.uk, etc.

Table 5: Normalised (lead = 1) price comparison between weights of different composition based on the midpoints between the minimum and maximum prices.

Type	Weight (g)	Lead	Tungsten	Brass	Composite	Iron/steel	Glass	Stones/ minterals	(Weighted) concrete
anchor lead	60-99	1,0			2,4				1,0
anchor lead	100-149	1,0			2,4				1,6
anchor lead	150-400	1,0			1,6				0,8
cannon ball lead	1-49	1,0	2,9	3,0	1,9				
cannon ball lead	50-99	1,0			1,8				
cannon ball lead	100-200	1,0			1,6				
bullet sinker	1-5	1,0	2,0	0,7	1,0	0,2		0,6	
bullet sinker	6-10	1,0	3,6	0,7	1,4	0,2		0,6	
bullet sinker	11-30	1,0		1,7	1,7	0,1			
dropshot pencil	3,5-5,0	1,0	2,2	1,5	1,2				
dropshot pencil	5,1-10,0	1,0	4,7	1,5	1,3				
dropshot pencil	10,1-28,0	1,0	7,4	1,5	1,4				
flexhead	1,0-5,0	1,0	1,5						
flexhead	5,1-10,0	1,0	2,5						
carplead, incl gripper lead	25-99	1,0			1,0				0,7
carplead, incl gripper lead	100-150	1,0			1,3				0,7
lead jighead (round)	1,8-19,9	1,0	3,2		1,4				
lead jighead (round)	20-50	1,0	3,1						
piramid lead	65 - 100	1,0			2,5				
piramid lead	100 - 200	1,0			1,9				
surfcasting lead	15-99	1,0			1,2		1,5	1,7	
surfcasting lead	100-230	1,0			1,5			2,5	
wreck fishing lead	100-249	1,0				2,0			
wreck fishing lead	250-349	1,0				2,3			
wreck fishing lead	350-500	1,0				1,3			

3.8 Usability of alternatives per fishing technique

Of course, among the alternative fishing weights available, there is no single one that meets all the technical performance requirements for every type of rod or fishing technique. But every type of lead fishing weight or lure can be successfully replaced by a selection of alternatives. Only for the smallest lead weights (<0.06 g), the alternatives are limited and have not yet been sufficiently subjected to practical tests by pole anglers. In the context of the European lead restriction proposal (ECHA 2021), a number of stakeholders have raised the issue of a potential loss of performance for anglers using alternative weights (e.g. impact on casting distance, flow interaction). It can indeed be argued that the behaviour and dynamics of alternative weights, both in the water and during casting, can differ from their lead counterparts due to their usually larger volume (i.e. lower mass density). However, these differences do not appear to affect the main technical functions or the usability of the fishing gear in both freshwater and marine fisheries and do not have a negative impact on fish performance, i.e. the quantities of fish caught (e.g. Niepagenkemper 2015, Aubry 2018, Crabbe and Herremans 2019, Bobbaers 2019, Verleye and Devriese 2019, ECHA 2021, Willems 2021). The different dynamics compared to lead may require some habituation by the angler, but does not impair the functionality.

During the casting test carried out with alternative fishing weights (iron powder with PHA-binder; mass density of ~5 g/cm³ <> lead 11.34 g/cm³) in the framework of the study by Verleye and Devriese (2019), the Belgian Surfcasting Club recorded a 5% reduction in casting distance in case of tailwind and about 10% with headwind. Similar results were obtained in casting tests with stone weights (Pomeroy 2021; Jaszkowiak 2021). However, these tests are aimed at determining the maximum casting distance of the object, which in practice is less applicable for most angling techniques. On the other hand, in a practical test conducted by a beach angler, an increase in casting distance was recorded with tailwind (Wintein 2019). Regarding the flow interaction, in the study by Verleye and Devriese (2019) no negative relationship could be found between the assessment of the flow interaction by boat anglers and the flow velocity at the time of the fishing activity. Willems (2021) had similar findings for boat fishing in Dutch marine waters.

Following the Resolution 'concerning the limitation of the use of environmentally harmful substances in sport fishing and the promotion of environmentally friendly alternatives' (16 March 2016; see also **2.2.2**), a written question (no. 1002) was submitted in the Flemish Parliament on 11 September 2020, addressed to Minister Demir, asking about the state of affairs regarding the formulated intentions. The answer included a description of the extent to which ecological alternatives had been adopted within the various fishing techniques. It was stated that lead-free alternatives are available for carp fishing, predatory fishing, fly fishing and feeder fishing. The availability of alternatives for whitefish (pole) fishing was found to be rather limited. The authors and lectors of this report took a closer look at these findings and made an overview of the most commonly used lead weights per fishing technique with an indication of the potential alternatives for both freshwater and marine fisheries (see table 6).

It can be stated that within each angling category, alternatives are offered commercially (e.g. Gerlach 2017), but generally, with the exception of fly fishing, their use is limited (table 6). Nevertheless, the performance of some alternatives equals (or exceeds) that of lead (e.g. Crabbe and Herremans 2019). In **predatory fishing**, tungsten appears to be a good substitute for lighter weight categories. For instance, a better bottom feel is recorded and the performance exceeds that of lead in terms of 'steering' the softbait, with the weight proving less susceptible to currents and wind. Furthermore, the material resulted in further casts and a decrease in material loss on stony bottoms is expected. A disadvantage, however, is that tungsten is the most expensive alternative, meaning that the use of tungsten to replace heavier weights is likely to be difficult. Also, the tungsten alloys used often contain carcinogenic elements such as nickel and cobalt, which again raises questions about the long-term environmentally friendly character of such alternatives (see **3.5.3** and **3.5.5**). Brass is a worthy alternative to lead from a functional perspective, but the material is still little known among recreational fishermen, partly due to the limited supply (Crabbe and Herremans 2019). The average cost of brass is about half that of tungsten (see **3.7**).

In **carp fishing**, both catches and hooking appear to be unaffected by the use of alternative weights (steel, (cast) iron, composite, stones/minerals) (Bobbaers 2019). In addition, the authors strongly advocate the use of stone fishing weights in carp fishing and this based on several positive properties: stones result in a perfect hooking, are a natural product, environmentally friendly and not expensive (Aubry 2018). Where lead acts merely as 'weight', the use of stone has multiple functionalities (weight, interaction with the environment/ biodiversity) and provides natural camouflage. Furthermore, due to its lower mass density, stones sink more slowly compared to lead and the chance of getting stuck is more limited, resulting in a reduced loss of fishing weights (Pomeroy 2021). Opinions are divided on the suitability of glass in carp fishing. Some consider the transparency to be an advantage, while others see the shiny surface as a disadvantage (Gerlach 2017). A limitation at present concerns the fact that the glass versions (both swivel and in-line variants) are only available up to a maximum weight of 57 g.

Fly fishermen are front runners when it comes to the use of lead substitutes in angling. Compared to other disciplines, fly fishing uses weighting only sporadically on artificial flies. After all, sinking fly lines, fluorocarbon nylon and heavy hooks can be used to fish metres deep without having to add a single milligram of weight to an artificial fly. Weighting the leader and flies/nymphs is even forbidden on many waters (e.g. international fly fishing competitions in England; 'Kluizen 2' - the reservoir of the Federation of Flemish Fly Fishermen). If weighting is considered necessary (e.g. in strong flowing waters), it is limited to a few fractions of a gram to a maximum of 1 to 2 g. At present, this weighting is usually done using brass or tungsten beads (Vinck 2019).

At **sea**, lead-free weights have found only limited acceptance. Nevertheless, environmentally friendly alternatives (concrete, (cast) iron, steel, composite) are also available for the various categories of marine fishing weights. The study by Verleye and Devriese (2019) already shows that weights made of composite (here iron with PHA-binder) are a fully-fledged alternative. These products do not appear to have a negative impact on catches and are assessed as moderately positive to positive in terms of performance (see also Willems 2021). In the Netherlands, the use of steel weights in sea angling is also possitively assessed (Derks 2017; see also **3.4**). Also the use of stone was already positively evaluated in Norwegian and Icelandic waters to depths of 100 metres and more (but needed some line adaptations) (Jaszkowiak 2021; www.mediafishingteam.de).

Table 6: Overview of the main categories of angling techniques with indication of the most commonly used lead types and grammages, the availability and effective use of alternatives, and potential lead substitutes. For your information: An overview of commercially available lead-free alternatives is currently also given on the website of Sportvisserij Nederland: www.sportvisserijnederland.nl/vis-water/sportvisserij-loodvrij/overzicht-loodalternatieven.

	Fishing technique	Alternatives		Lead types (inline + swivel)	Common weights (g)	Alternatives	Remarks
		Availability	Use				
FRESH	Carp fishing	+	+/-	In-line lead	10-60	Composite, concrete, stone, steel, tungsten, brass, glass	
				Disc/Gripper lead	30-300	Composite, concrete, stone, steel, (cast)iron	
				Cannon ball lead	40-160	Composite, concrete, stone, steel, tungsten, brass, (cast)iron	
				Casting lead	40-300	Composite, concrete, stone, steel, glass, (cast)iron	
					1-2	Tungsten putty	
	Predatory fishing	+	+/-	In-line lead	5-40	Composite, concrete, steel, tungsten, brass	
				Split shot	2-10	Tungsten, composite, stone(?), iron (?)	
				Swivel (≠ shapes)	5-40	Composite, concrete, stone, steel	
				Jighead	5-60	Composite, concrete, tungsten	Mass density of great importance (subtlety)
				Pilker	20-200	Tungsten, composite	
				Dropshot weights	1-14	Composite, concrete, tungsten, brass	Mass density of great importance (subtlety)
				Weighted floats	10-50	Composite	Use in combination with living bait (predatory fishing)
				Spinners/plugs	2,5-10	Tungsten, brass, steel	To date, they rarely contain lead
	Fly fishing	+	+	Beads	0.06 - 2	Tungsten, brass, composite, steel	
				Lead wire	nvt	Tungsten	Rarely used (<10% of fishermen)
	Feeder fishing	+	+/-	Feeders	10-50	Composite, steel, (cast)iron	Mass density and aerodynamics of little importance (no self-hooking system)
	Pole fishing (whitefish)	-	-	Sounding line	5-60	Composite	Mass density of great importance
				Split shot	0.06-2	Tungsten, composite	

	Fishing technique	Alternatives		Lead types (inline + swivel)	Common weights (g)	Alternatives	Remarks
		Availability	Use				
SALT	Active beach angling	+/-	-	Jighead	30-60	Composite, concrete, tungsten	Mass density of great importance (subtlety)
				Pilker	60-100	Tungsten, composite	Rarely used
				Weighted floats	10-50	Composite	Use in combination with living bait (predatory fishing)
				In-line lead and split shot	1-2	Tungsten, composite	Fly fishing at sea
	Passive beach angling	+/-	-	Anchor lead	140-180	Composite, steel, (cast)iron	Mass density and aerodynamics are important. Pyramid, cannon ball and disc/gripper leads are mainly used in fisheries at 15-60 m water depth
				Piramid lead	100-140	Composite, concrete, steel, (cast) iron	
				Casting lead	120-160	Composite, steel, (cast)iron	
				Cannon ball lead	80-120	Composite, steel, (cast)iron, concrete, tungsten, brass	
				Disc/Gripper lead	80-120	Composite, concrete, stone, steel	
	Active boat angling	+/-	-	Jighead	10-100	Composite, concrete, tungsten	Mass density of great importance (subtlety)
				Pilker	50-150	Tungsten, composite	Rarely used
				Swivel lead	80-120	Composite, steel, (cast)iron, concrete, stone	
	Passive boat angling	+/-	-	Anchor lead	150-200	Composite	
				Fixed anchor lead	200-300	Composite	Use in strong currents and deeper water
				Piramid lead	150-200	Composite, concrete, steel, (cast) iron	Use when there is little flow
				Casting lead	100-150	Composite, (cast)iron	Rarely used
				Cannon ball lead	100-150	Composite, steel, (cast)iron, concrete, brass	Rarely used, only in case of little flow
				Swivel lead	120-150	Composite, steel, (cast)iron	

A bottleneck at present is the often limited availability of alternatives in angling shops. An increased supply will benefit the sale of lead-free alternatives. Nowadays, fishermen often have to turn to and delve into online sales platforms to get an idea of the range of environmentally friendly products (e.g. Bobbaers 2019). An improved distribution of these alternatives to angling shops should therefore be a priority in the lead phase-out process.

4. Conclusions

- **Lead** is considered a **priority substance** at international, regional, European and national level, and its **toxic effects** on the environment (fauna and flora) and human health have been widely scientifically demonstrated. Preventing lead from spilling into the aquatic environment is therefore addressed in several international conventions ratified by Belgium and is also part of the federal programme of measures for the Belgian marine waters in implementation of the European Marine Strategy Framework Directive.

- The **combination of a sales ban and a ban on the use** of lead sinkers and lead-containing lures is the most effective approach. Only a ban on use may encourage illegal use, as lead may still be offered in angling shops in such a situation. Enforcement should be a central pillar in such a scenario. A sales ban alone will lead to more purchases from non-European online shops (often without quality guarantees) and may increase home-casting of lead, with the associated health risks.

- The ECHA restriction proposal on lead fishing weights is in a consultation phase. The degree of integration of the currently formulated objectives (i.e. lead ban with transitional periods) within a European legal framework (foreseen for 2023) is still subject to the contributions by stakeholders, the opinions of the Risk Assessment Committee (RAC) and Socio-Economic Analysis Committee (SEAC), as well as the vote of the individual Member States. Regardless of the final outcome, the current European trajectory offers an excellent opportunity to create support among the Belgian/Flemish stakeholders and to develop a **national restriction framework**. Such a national framework, where Belgium can play a pioneering role, must consider the **protection of the environment and human health** as the main principles and offers a **national legal basis in case the European ambitions are tempered**. Such a national approach requires **cooperation between competent federal and regional authorities** within the Belgian state structure. A wait-and-see attitude, combined with the current uncertainty about the final European outcome in this dossier, therefore entails risks, as the creation of a national basis of support after a possible weakening of the European ambitions (which is not currently being assumed) may become very difficult. Notwithstanding the fact that a national approach will probably fail to stimulate international lead producers to develop and invest in lead-free alternatives, the producers of environmentally friendly alternatives have indicated that they can quickly (2 months to 2 years) scale up their production capacity.

- A **phase-out period** for lead fishing weights of three (<50 g) or five (>50 g) years, as proposed by ECHA (with the exception of drop-off systems, which are banned with immediate effect), starting from the entry into force of the regulation (foreseen in 2023), involves **risks for a continued lead production** until the effective ban date. In 2015, the European Fishing Tackle Trade Association (EFTTA) already called for the voluntary phasing out of the production, import, sale and use of lead >0.06 g by 2020 at the latest and its replacement by suitable alternatives. However, until now, little visible efforts have been made by the large-scale angling industry to this end. Furthermore, the rather arbitrary distinction between the phase-out periods for lead weights <50 g and >50 g within the European restriction proposal is questioned. This distinction was made purely on the basis of the impact of smaller fishing weights on waterbirds (ingestion) and does not take into account the environmental impact that larger weights can have on numerous other organisms.

- The **budgetary impact** of (more expensive) eco-friendly alternatives on the total annual hobby-related expenditure of **fishermen** is **limited** (3% increase of the average total fishing budget). Furthermore, the different dynamics of **alternatives** (compared to lead) do not seem to influence the main technical functions and usability of the fishing gear and **do not have a negative effect on the fishing performance**, i.e. the quantities of fish caught. Fishing with alternatives may require some habituation by the fisherman, but it does not affect the functionality of environmentally friendly fishing weights. At present, **a feasible alternative is offered for each type of fish weight** (with the exception of fishing weights <0.06 g, for which the functionality of alternatives could not yet be unequivocally demonstrated), and the producers of these eco-friendly alternatives indicate that they can **scale up quickly**. In this way, fishing in an environmentally friendly way offers a benefit to both people and the environment so environmentally conscious fishing becomes a shared mentality among the new generation of anglers, because a healthy ecosystem will directly result into increased fishing pleasure.

- **It must be ensured that the phase-out of fishing lead**, with an estimated annual loss of 10 to 17 tonnes in Belgian public waters, **does not lead to the use of other polluting or scarce materials**. At present, several lead-free alternatives contain heavy metals (zinc, cobalt, nickel, etc.), which in turn pollute the environment or public health, and some of which are already characterised by a high number of exceedances in the Flemish public hydrographic network (cobalt and zinc at 53% and 10% of the monitoring sites, respectively) and in marine sediments (zinc at 90% of the monitoring sites). Consequently, the focus should primarily be on weights made from (mainly) natural raw materials that do not cause demonstrable health or environmental problems, such as stones, boulders, (cast)iron, (bio)composites, concrete, unalloyed steel and glass, and further research into (binding) bio-composites is strongly encouraged.

- In addition to **stimulating/facilitating** the **supply of environmentally friendly lead alternatives to angling shops** (currently limited supply), attention should also be paid to **increased transparency regarding the composition of so-called 'non-toxic' or 'lead-free' fishing weights**. An obligatory description of the actual composition on online web shops and in angling shops will enable the angler to make environmentally conscious choices. 'Non-toxic' is often used as an alternative to 'lead-free', but without an elemental analysis it is impossible to determine whether the alternative can be considered environmentally friendly.

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